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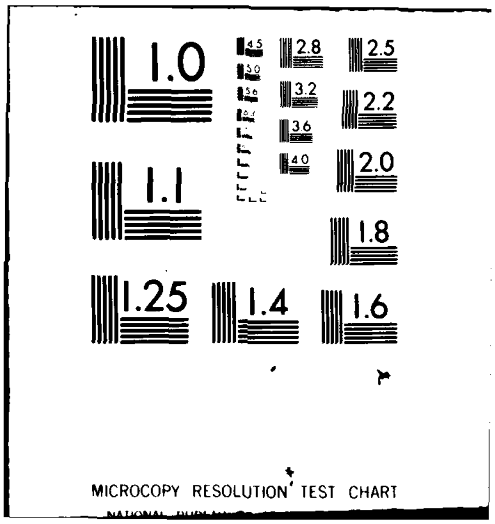

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Report DELNV-TR-0019

OBSERVER PERFORMANCE MEASURED AGAINST HYBRID COMPRESSED VIDEO IMAGERY

by
Joseph E. Swistak

March 1981

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U.S. ARMY ELECTRONICS R&D COMMAND
NIGHT VISION & ELECTRO-OPTICS LABORATORY
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A study was conducted in which the effects of bits per pixel reductions on target detection and recognition were measured. A hybrid DCT/DPCM compression algorithm was used to manipulate the bit-per-pixel reduction rate. The algorithm was implemented in the form of a software simulation package on a general-purpose minicomputer facility. Using this facility, real-time imagery was reduced from analog to 8- and 2-bit-per-pixel levels at 1-frame-per-second update rates. Observers were asked to detect and recognize targets located in the imagery.

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Average detection and recognition slant ranges were calculated for each target and compression level. No significant differences in performance were noted due to the different compression levels.

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OBSERVER PERFORMANCE MEASURED AGAINST HYBRID COMPRESSED VIDEO IMAGERY

INTRODUCTION

The U.S. Army currently has a contract for the development of a Modular Integrated Communication and Navigation System (MICNS) which will be used as a communication link for such remote sensors as RPV and SOTAS. Since the communication link is RF, a means of reliably providing antijam (AJ) protection for the transmission of reconnaissance image data must be provided. A video image compression system is currently being developed along with and integral to the MICNS system which will provide this AJ protection. Current design has the bandwidth compression system consisting of a hybrid processor which uses a combination of a discrete cosine transform (DCT) followed by a differential pulse code modulation (DPCM) encoding of the resulting frequency coefficients to achieve intraframe compression.

One of the greatest concerns of developers is how much the video can be compressed before the performance of the operator falls below acceptable levels. The current planned spatial reduction level is 2 bits per pixel. The information refresh rate will vary from 1 to 15 frames per second. As presently planned, there are 19 different possible combinations of bit-per-pixel and frame rates which the operator will be able to choose from.

Until recently, the effects of various spatial compression levels have been determined by subjectively comparing a given level of reduction on a single frame to the original frame. This technique, although adequate for a laboratory quick-look assessment, falls far short of providing accurate and definitive data for an operational scenario. The frame-to-frame integration performed by the eye during a typical dynamic flight goes a long way toward smoothing the scene being viewed. It seems, therefore, that a better approach to measuring the effects of various compression levels on video information would be to perform the compression on a sequence of video frames rather than on just one frame.

Such a study[1] was conducted using an HAAR transform[2] to perform the spatial compression. These results indicated a 20-percent loss in detection and recognition

[1] J. E. Swistak, *Bandwidth Compression: Its Effect on Observer Perofrmance.* SPIE Proceedings (Fall 79).

[2] T. Leibhoff, H. Henning, T. Noda, and B. Deal, *Final Report for Experimental Development of a FLIR Sensor Processor.* Technical Report 77Y106, Northrup Corporation, Anaheim, California (September 77).

range when the bits per pixel were reduced from 8 to 2.

More recently, a software simulation package was developed by the Lockheed Palo Alto Research Laboratory.[3] This facility is currently programmed to use the hybrid DCT/DPCM compression algorithm which will be used in the MICNS communications link. This facility was used to compress a subset of the imagery used in the previously referenced study. This imagery was then used as the stimulus material in a similar but much less exhaustive study of bandwidth compression effects on observer performance.

METHOD

Observers. Twenty paid volunteers (1 male; 19 females) served as subjects. None had prior experience with an RPV system or with military target detection in general.

Apparatus. The subjects were required to view a 15-inch (38 cm) black-and-white video monitor (Ball Miratel Model BH-15). The video stimuli were two "runs" selected from a set of actual flight-test recordings of an RPV system being evaluated at Fort Huachuca, Arizona. A run comprised a single straight and level flight segment oriented so as to fly toward and over a specified target on the ground. Both runs were made at the same altitude (500 meters), heading, and ground speed (50 knots). Both runs were made over the same section of terrain. The only conditions to vary between the two runs were the type and location of the target. One run contained an APC; the other, a 5/4-ton truck. Both targets were located in off-road positions. These runs were a subset of those used in the study by Swistak[4] and were processed at three levels. The first level was simply a throughput compression; i.e., the tape was played through the facility without any frequency compression. This was effectively an analog-to-analog recording with only the electronics noise in the system having an effect. The analog tape was then played through again and digitized to 8 bits per pixel. The third level was a compression to 2 bits per pixel from the original analog tape. For each compression level, the same frames of video were selected and processed to prevent any anomalies in the performance data due to frame-to-frame variation. This resulted in a set of 6 target runs of approximately 145 seconds duration. Since each target run would be presented three times, there was some concern that the observers would recognize this fact and respond in an apriori fashion. To minimize this effect, 7 additional runs from a previous test were selected and alternated with the 6 test runs. The test runs were presented in a random fashion rather than sequentially to prevent an order effect in the results.

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[3] K. Dutta, and M. Millman, *Dynamic Simulation of Hybrid Video Compression.* SPIE Proceedings (Fall 80).

[4] J. E. Swistak, *Bandwidth Compression: Its Effect on Observer Performance.* SPIE Proceedings (Fall 79).

During this study, the equipment was arranged so that four observers could be tested simultaneously. Each observer performed in a cubicle that was visually isolated from the other three observers.

Each observer responded to the video stimuli by means of a set of six switches mounted on a single control box. The functions of the switches were as follows: Number 1 was used to report "target detection"; numbers 3 through 6 were used to report recognition of the jeep, 5/4-ton truck, 2½-ton truck, and armored personnel carrier, respectively. Number 2 switch was designated as "reset" and was used by the observer to cancel any responses made within a trial as, for example, to cancel an incorrect "target detected" response when, upon closer inspection of the scene by the observer, that response proved to be in error.

Procedures. Observers were randomly assigned to 5 experimental groups of 4 observers each and scheduled for participation in the experiment. The first part of each session was devoted to orientation and practice. Formal data collection then followed with all tests on any observer being completed within a 2-hour time period.

Each observer viewed a total of 26 runs – 2 sets of 13. Six of the 13 were actual test runs; 7 were fillers. The fillers were used to prevent the observers from realizing the actual test runs were the same two target runs being repeated. The order in which the 13 runs were shown to the observers was always the same. The observers were shown the first set of 13 runs, given a break, then shown the same 13 runs a second time. This resulted in two complete sets of data. For each data trial (run) an observer had an opportunity to make a detection response and a recognition response by pressing the corresponding switches on his/her panel. A trial was considered valid and recognition data were recorded only if a target was recognized correctly. Observer responses were recorded against a time line commencing with the start of each trial. Given this measure of elapsed time plus the speed and altitude of the photographic aircraft, it was possible to calculate the respective detection and recognition ranges.

RESULTS AND DISCUSSION

Preliminary analysis indicated a significant difference in the results for session one versus session two, thus precluding the use of the data as a combined set. As can be seen in Table 1, the means for session two are considerably greater for both targets regardless of compression condition. The conclusion here was that observer training was not completed prior to the presentation of session one and resulted in the significant increase in performance on session two. Therefore, it was felt that session two data more accurately reflected the performance a trained observer would exhibit. Because of this, only session two data were used for further analysis.

Overall, the mean detection range, as a function of bits per pixel, did not vary significantly. Figure 1 presents the detection data for bit-per-pixel effects for the APC and the 5/4-ton truck. The analysis showed a significant difference for the results *between* targets ($F(1,38) = 13.59$, $p > .01$). However, no significant difference was obtained between the compression levels ($F(2,76) = 0.11$, $p < .01$). These results indicate that no significant loss in detection performance occurs when video imagery is spatially compressed to 2 bits per pixel and displayed at 1 frame per second using the hybrid transform technique described earlier.

The statistical results and visual impressions conveyed in Figure 1 appear at odds, due to the dip and hump for the APC and 5/4-ton truck target, respectively. At first, it was felt that the order of presentation might account for the variation. The circled numbers above the data points in Figure 1 indicate the order in which each target and spatial compression combination were presented. It can be seen that no consistent trend can be accounted for due to the order of presentation. Examination of both the video tapes and data provided no rational reason why the larger excursions in the curves are present. At best, the variation can be described as an experimental anomaly which did not have a significant effect.

A similar analysis was conducted on the recognition data. The mean recognition ranges, shown in Table 2, do not have as clear a distinction between the session one and the session two data. This is especially true in the case of the 5/4-ton truck. Nevertheless, for reasons of consistency, only the session two data were used for further analysis.

Overall, the mean recognition range, as a function of bits per pixel, did not vary significantly. Figure 2 presents the recognition data for bit-per-pixel effects for the APC and the 5/4-ton truck. The analysis showed a significant difference for the results between targets ($F(1,38) = 22.47$, $p > .01$). However, no significant difference was obtained between the compression levels ($F(2,76) = 4.76$, $p < .01$). These results indicate that no significant loss in recognition performance occurs when video imagery is spatially compressed to 2 bits per pixel and displayed at one frame per second using the hybrid transform technique described earlier.

Once again, the visual impressions conveyed in Figure 2 do not appear substantiated by the statistical results. However, the large variation in the data shown as the standard deviation in Tables 1 and 2 does play a major role in accounting for the non-significant results. Figure 3 shows the APC target at minimum range for all three information levels (a) analog, (b) 8 bits per pixel, (c) 2 bits per pixel.

Table 1. Mean Detection Ranges and Standard Deviations for the APC and 5/4-Ton Truck Targets

			Analog	8-Bit	2-Bit
APC	Session 1	$\bar{x}$	2411	1828	2235
		s	298	372	388
	Session 2	$\bar{x}$	2631	2289	2540
		s	140	238	263
5/4	Session 1	$\bar{x}$	1375	1813	1784
		s	164	246	306
	Session 2	$\bar{x}$	1670	2081	1906
		s	318	256	511

Table 2. Mean Recognition Ranges and Standard Deviations for the APC and 5/4-Ton Truck Targets

			Analog	8-Bit	2-Bit
APC	Session 1	$\bar{x}$	1252	922	1257
		s	442	345	418
	Session 2	$\bar{x}$	1509	1182	1454
		s	494	327	413
5/4	Session 1	$\bar{x}$	550	791	950
		s	0	316	417
	Session 2	$\bar{x}$	588	738	840
		s	53	229	232

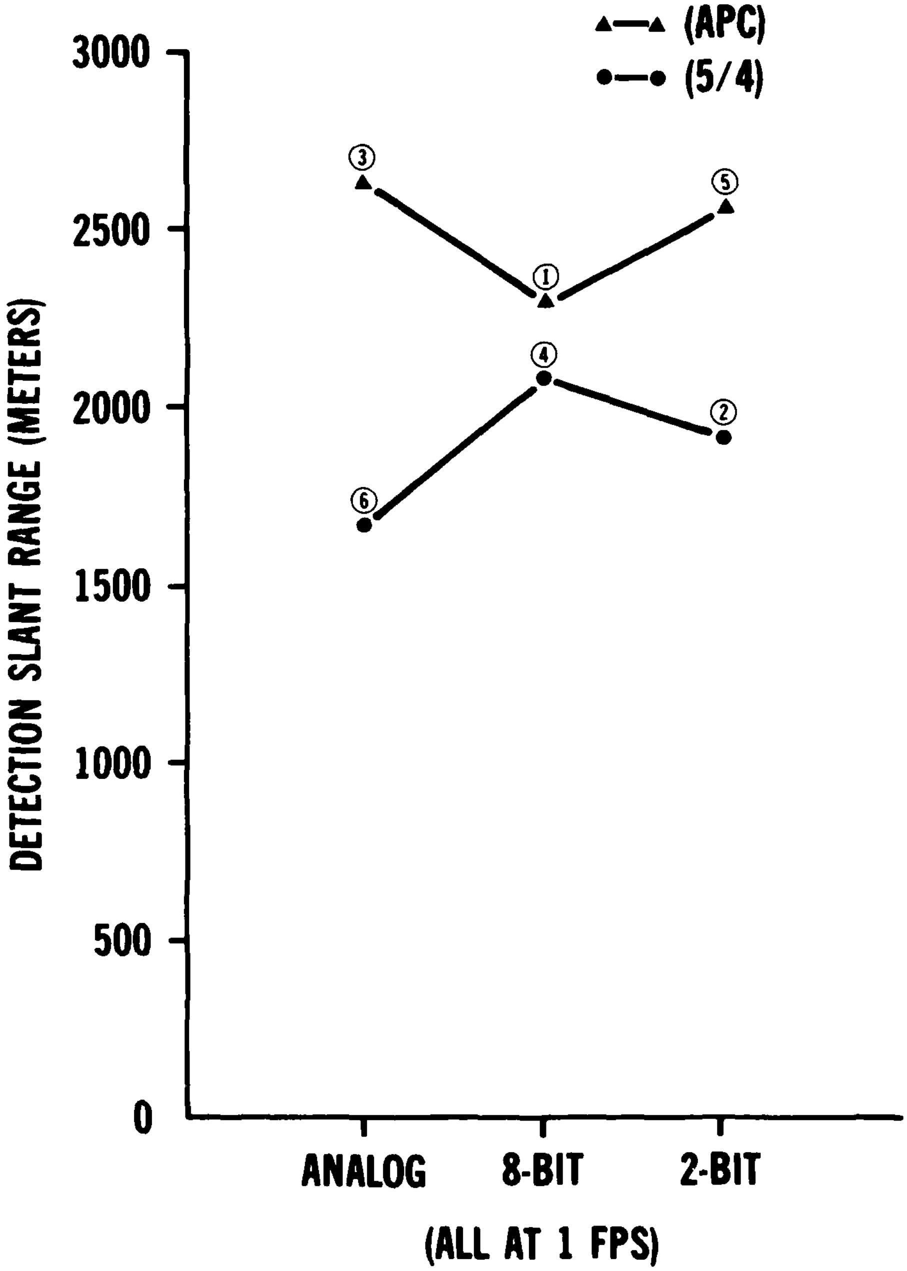


Figure 1. Mean detection ranges as a function of bits-per-pixel for the APC and 5/4-ton truck.

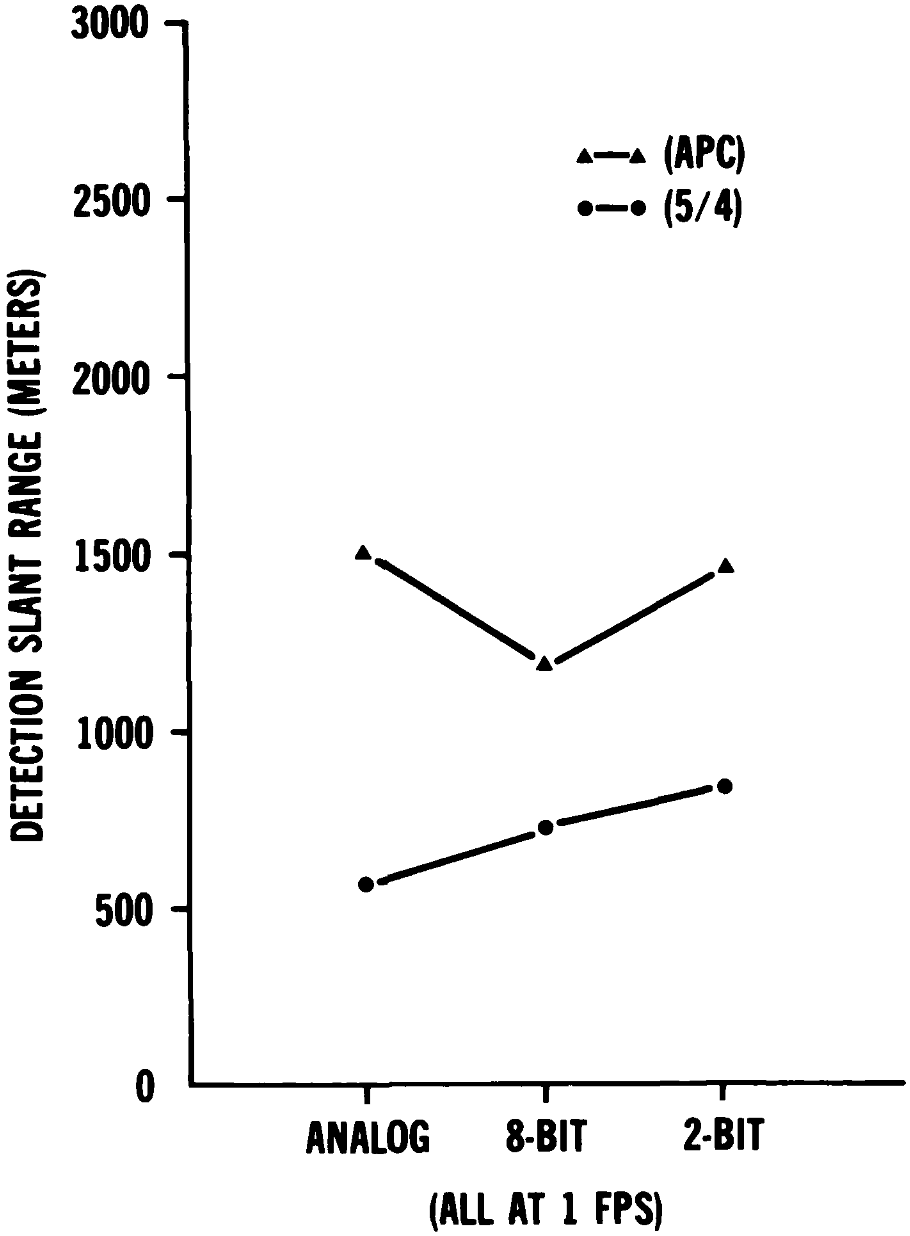
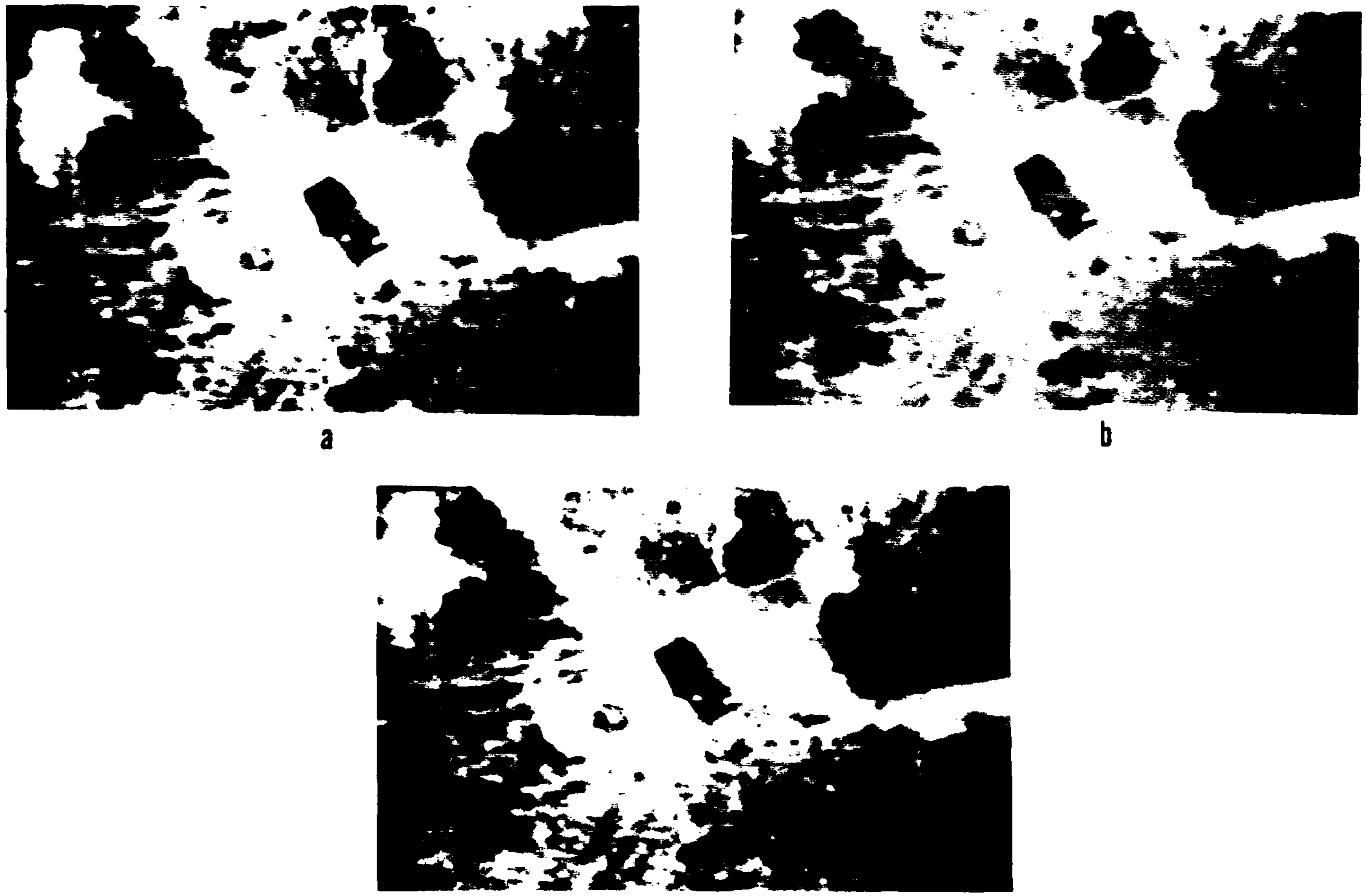


Figure 2. Mean recognition ranges as a function of bits-per-pixel for the APC and 5/4-ton truck.



a b c

Figure 3. The APC target at minimum range for all three information levels: (a) analog, (b) 8 bits per pixel, (c) 2 bits per pixel.

CONCLUSIONS

Two major results are evident: First, the bit-per-pixel variation did not significantly affect observers ability to detect or recognize targets. Second, the type of target did have an effect. The results for the two targets used here are distinctly different.

For any future studies, it would be wise to select targets which more closely resemble one another either in size or shape. This would allow the data to be combined across targets and would lessen the variation in the results. Furthermore, the differences between individual observers should be minimized. This could be accomplished by training each observer to a given level of proficiency rather than by giving all observers the same amount of training. The short lead time and immediate need of the results precluded such a training method from being used in this study. However, any future studies would benefit greatly by using such a training technique.

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